World's Smallest Ultraviolet Nanolasers Developed

As reported in the June 8, 2001 issue of *Science*, an interdisciplinary team from the Berkeley Lab Materials Sciences and Energy Environmental Technologies Divisions has fabricated and tested the world's smallest ultraviolet-emitting lasers. This breakthrough has a broad range of potential applications in fields ranging from photonics, the use of light for superfast data processing and transmission, to the so-called "lab on a chip" technology in which a microchip equipped with nano-sized light sources and sensors performs instant and detailed analyses for chemistry, biology, and medical studies.

Over the last decade, progress in semiconductor laser research has led to the development of new materials that promise to extend the availability of versatile and inherently inexpensive (a few cents per unit in bulk quantities) light sources from the currently accessible near infrared and red regions of the spectrum into the green-blue and near ultraviolet. Much of this research has concentrated on gallium nitride and its alloys with indium nitride and aluminum nitride. Zinc oxide also has a relatively wide band gap (3.4 eV) which makes it potentially attractive as a semiconductor laser material in the near-ultraviolet; indeed, there have been promising recent reports of laser action in ZnO thin films and particles.

Light emission in semiconductor lasers is caused by the "recombination" of negatively charged electrons and positively charged "holes." In general, a semiconductor will "lase" if the density of these charge "carriers" exceeds a certain "threshold current." Making an efficient and practical laser involves making this threshold current as small as possible.

The recombination mechanism in ZnO becomes more efficient as the crystals become smaller, so Yang's group developed a new method, "catalyzed epitaxial crystal growth," to make organized arrays of uniformly-sized ZnO nanocrystals. They deposited a patterned thin film of individual gold nanoclusters on a sapphire substrate. When this was exposed to gaseous ZnO, oriented single crystals of ZnO grew on the nanoclusters. As shown in the figure, this produced arrays of "nanowires," between 70 and 100 nm in diameter, whose length could be controlled to between 2 and 10 microns by adjusting the time of growth.

Because it is not yet possible to make electrical contacts to the ZnO nanowires, pulsed lasers were used to create charge carriers in the wires. At low "pump powers" the emission spectrum was broad, indicating ordinary light emission. However, above a certain threshold pump power, a narrow emission spectrum was observed from the wires, consistent with "stimulated" light emission and laser action (see figure). It is thought that the ends of the nanowires form the mirrors that define the laser cavity in which the stimulated emission bounces back and forth, creating the amplification that produces laser light (see figure).

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Michael H. Huang, Samuel Mao, Henning Feick, Haoquan Yan, Yiying Wu, Hannes Kind, Eicke Weber, Richard Russo, Peidong Yang, "Room-Temperature Ultraviolet Nanowire Nanolasers," *Science* 292, 1897 (2001).